ENVIRONMENTAL BARRIER MATERIAL FOR ORGANIC LIGHT EMITTING DEVICE AND METHOD OF MAKING

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of U.S. patent application Ser. No. 09/427,138, filed Oct. 25, 1999 entitled "Environmental Barrier Material for Organic Light Emitting Device and Method of Making" which is a continuation-in-part of U.S. patent application Ser. No. 09/212,779, filed Dec. 16, 1998, now U.S. Pat. No. 6,268,695 entitled "Environmental Barrier Material for Organic Light Emitting Device and Method of Making."

The present invention relates to organic light emitting devices (OLEDs), and more particularly to OLEDs encapsulated in barrier stacks.

There is a need for versatile visual displays for electronic products of many different types. Light emitting diodes (LEDs) and liquid crystal displays (LCDs) have found many useful applications, but they are not adequate for all situations. OLEDs are a relatively new type of visual display which has shown great promise. An OLED basically includes an organic electroluminescent substance placed between two electrodes. When an electric potential is applied across the electrodes, the electroluminescent substance emits visible light. Typically, one of the electrodes is transparent, allowing the light to shine through. U.S. Pat. Nos. 5,629,389 (Roitman et al.), 5,747,182 (Friend et al.), 5,844,363 (Gu et al.), 5,872,355 (Hueschen), 5,902,688 (Antoniadis et al.), and 5,948,552 (Antoniadis et al.), which are incorporated herein by reference, disclose various OLED structures.

The use of OLEDs in flat panel displays and other information display formats is limited by the poor environmental stability of the devices. G. Gustafson, Y. Cao, G. M. Treacy, F. Klavetter, N. Colaneri, and A. J. Heeger, Nature, Vol. 35, Jun. 11, 1992, pages 477–479. Humidity and oxygen significantly reduce the useful life of most OLEDs. As a result, these devices are typically fabricated on glass substrates with glass covers laminated on top of the OLED and with the edges sealed to exclude water and oxygen from the active layers. U.S. Pat. No. 5,872,355 discloses the use of a polymer such as saran to seal the device. The water vapor permeation rates (WVTR) required to provide sufficient lifetime for OLEDs is calculated to be approximately 10^{-6} g/m^2/day. The best polymer films (such as saran) have WVTR values that are 5 orders of magnitude too high to be considered for OLED encapsulation. Furthermore, saran cannot be deposited using flash evaporation, condensation, and in situ polymerization within a vacuum chamber.

Thus, there is a need for an improved lightweight, barrier construction which can be used to encapsulate the OLED and prevent the deterioration caused by permeation of oxygen and water vapor and for a method of making such an encapsulated OLED.

SUMMARY OF THE INVENTION

These needs are met by the present invention which is an encapsulated organic light emitting device (OLED). In one embodiment, the encapsulated OLED includes a substrate, an organic light emitting device adjacent to the substrate, and at least one first barrier stack adjacent to the organic light emitting device, the at least one first barrier stack comprising at least one first barrier layer and at least one first decoupling layer, wherein the at least one first barrier stack

encapsulates the organic light emitting device. By 'adjacent,' we mean next to, but not necessarily directly next to. There can be additional layers intervening between the adjacent layers.

Optionally, there can be at least one second barrier stack adjacent to the organic light emitting layer device and located between the substrate and the organic light emitting device. The second barrier stack has at least one second barrier layer and at least one second decoupling layer. The first barrier stack can be substantially transparent, the second barrier stack can be substantially transparent, or both the first and second barrier stacks can be substantially transparent, depending upon the particular application. At least one of the first or second barrier layers may be made from a material including, but not limited to, metals, metal oxides, metal nitrides, metal carbides, metal oxynitrides, metal oxyborides, and combinations thereof. Metals include, but are not limited to, aluminum, titanium, indium, tin, tantalum, zirconium, niobium, hafnium, yttrium, nickel, tungsten, chromium, zinc, alloys thereof, and combinations thereof. Metal oxides include, but are not limited to, silicon oxide, aluminum oxide, titanium oxide, indium oxide, tin oxide, indium tin oxide, tantalum oxide, zirconium oxide, niobium oxide, hafnium oxide, yttrium oxide, nickel oxide, tungsten oxide, chromium oxide, zinc oxide, and combinations thereof. Metal nitrides include, but are not limited to, aluminum nitride, silicon nitride, boron nitride, germanium nitride, chromium nitride, nickel nitride, and combinations thereof. Metal carbides include, but are not limited to, boron carbide, tungsten carbide, silicon carbide, and combinations thereof. Metal oxynitrides include, but are not limited to, aluminum oxynitride, silicon oxynitride, boron oxynitride, and combinations thereof. Metal oxyborides include, but are not limited to, zirconium oxyboride, titanium oxyboride, and combinations thereof.

Substantially opaque barrier layers can be made from opaque materials including, but not limited to, opaque metals, opaque polymers, opaque ceramics, opaque cermets, and combinations thereof. Opaque cermets include, but are not limited to, zirconium nitride, titanium nitride, hafnium nitride, tantalum nitride, niobium nitride, tungsten disilicide, titanium diboride, zirconium diboride, and combinations thereof.

The barrier layers in the first and second barrier stacks can be made of the same material or a different material. Barrier layers within the first or second barrier stacks can be the same or different.

The substrate can be either a flexible substrate or a rigid substrate. Flexible substrates include, but are not limited to, polymers, metals, paper, fabric, glass, and combinations thereof. Rigid substrates include, but are not limited to, ceramics, metals, glass, semiconductors, and combinations thereof.

The decoupling layers of the first and second barrier stacks can be made from materials including, but not limited to, organic polymers, inorganic polymers, organometallic polymers, hybrid organic/inorganic polymer systems, and silicates. Organic polymers include, but are not limited to, (meth)acrylates, urethanes, polyamides, polyimides, polybutylenes, isobutylene isoprene, polyolefins, epoxies, parylene, benzocyclobutadiene, polynorbomenes, polyarylethers, polycarbonate, alkyds, polyaniline, ethylene vinyl acetate, and ethylene acrylic acid. Inorganic polymers include, but are not limited to, silicones, polyphosphazenes, polysilazne, polycarbosilane, polycarborane, carborane siloxanes, polysilanes, phosphonitriles, sulfur nitride poly-